Lockdown Monitoring - IIIT-H Campus

*A lockdown Monitoring Software system for the IIIT-H Campus

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***Abstract*—In this paper, I go over the previous attempts that were made to develop systems that enforce lockdown measures and based upon those propose a novel system specifically designed for IIIT-H Campus that will ensure student safety. The proposed software system meets the need felt by the institute for identifying clusters of people via surveillance, and to try and restrict the movement of residents in the campus until it becomes normal. It features the ability to study the area wise distribution of clusters of various places across the campus at different times , live, feature various user profiles, a mobile app , a web interface, machine learning models to model campus events and predict fall out based on various factors. The proposed system is inspired by the previous attempts and uses technologies such as Bluetooth Low Energy, CCTV Surveillance, Face detection, Drones, Robots, WiFi etc to monitor, sanitise , predict and model a better and safe campus. The system tries to be cost effective by utilising the already existing infrastructure in the campus such as WiFi, CCTV. Bio metric systems etc. It will help the campus residents stay safe during this pandemic.**

I. Introduction

The COVID 19 pandemic is the defining global health crisis of the century. It has affected many lives over the past year. It is caused by severe acute respiratory syndrome coronavirus 2 (SARS CoV 2). The year 2020 was highly devastating and ended up in complete lockdown. The IIIT-H Campus remained closed and all functioning was done through online semesters managed remotely through Teams and other services. It was looking as though things were getting back to normal in 2021 and the campus opened up to students and started receiving students, especially research students back into campus. But then the second wave of COVID started. Cases started increasing around India. India's deadly Covid-19 second wave has devastated big cities like Delhi, Mumbai, Lucknow and Pune. Hospitals and crematoriums have run out of space, and funerals are taking place in car parks. But the pandemic has now firmly gripped many smaller cities, towns and villages where the devastation is largely under-reported. Students and Faculty alike have started acquiring the virus inside the campus too. There is a need felt by the institute for identifying clusters of people via surveillance, and to try and restrict the movement of residents in the campus until it becomes normal. With the institute on the brink of a lockdown and the gocoronago app not installed widely among students there is a need for a large system to manage the lockdown effectively inside the campus. The solution must be capable of displaying live maps to all users at all points, and notifications in case of close approach to a cluster to the user as well as administration. You may also alert if they are found to roam without masks. The solution must be robust and easy to manage, and something which all campus residents,the staff, faculties and students can install and use.The challenges include managing crowds inside the campus, avoiding close contacts, managing workspaces, labs , messes and other facilities. This requires to develop a software system that utilises technologies like AI, ML, drones, BLE, WiFi etc . to monitor the lockdown. This paper tries to go over the existing solutions and propose a novel solution specifically for the IIIT-H Campus and its students.

II. Literature Review

A lot of research has been done recently into methods of tracking people to enforce lockdowns, curfews and quarantines. There are different tracking and surveillance mechanisms being tested and implemented around the world. In this section we will look at some of them.

A. Apps by Governments

There have been various attempts to track people and their contacts by various governments around the globe including India to track crowds, contacts etc [1] [17]. Smartphone apps and other digital technology have been widely used to help limit the spread of the virus by almost all countries. For example, in Australia, using a Bluetooth wireless signal, the COVIDSafe app developed by the government , allows health officials to access crucial information about a person's interactions. In China [6] , codes need to be scanned before boarding buses and trains or entering airports, offices and even their own housing complexes. Different colors on the apps indicate different levels of risk, with green codes granted unrestricted movement, yellow codes for seven days of quarantine, and red codes for those who required 14 days of quarantine. The apps can trace whether users have been in contact with infected people. In South Korea, they will begin strapping electronic wristbands. The Indian government has launched a smartphone app called AarogyaSetu. The data, in this case, will be stored on users' phones. ISRO has been working on data visualisations for effective crowd management [21]

B. Implementations at Workplaces for Social Distancing

In many workplaces surveillance cameras and artificial intelligence are tackling a pandemic-era challenge: making sure workers are wearing face masks and staying at least six feet apart. [19] Cameras that were already in place in these

Application	Function	Origin
nCapp	· Keeps database updated	China
	· Provides available consulting	
	· Controlling patient's long-term health	
DetectaChem	· Taking COVID-19 low-cost tests using a kit connected to a smartphone application	USA
Stop Corona	· Getting daily health reports including contacts, symptoms, and locations	Croatia
	· Building a map with high risk spots	
Social Monitoring	· Track patients diagnosed with COVID-19	Russia
	· Access to the user's information by government (privacy concern)	
Selfie app	· Monitoring patients by asking randomly to send selfies	Poland
Civitas	· Determining perfect time for suspected cases to leave for essentials	Canada
StayHomeSafe	· Monitoring arrivals at the airport with use of smartphone application and a wristband	Hong Kong
Aarogya Setu	· Linking people and health services better	India
TraceTogether	· Capturing the people who were close to the user with encrypted IDs	Singapore
	· Access to the user's information by government (privacy concern)	
	· Notifying people who were in close contact with the user if the user is infected	
Hamagen	· Finding out if the user has been in close contact with a person who has tested positive for COVID-19	Israel
Coalition	· Securely notifying about detected cases who users have been in contact with	USA
BeAware Bahrain	· Alerting people who have been in close contact with infected person	Bahrain
	· Track self-isolated people	
	· Location services must be ON	
eRouska (smart quarantine)	· Capturing physical contacts between user and people	Czech Republic
Social Media – Whatsapp	· Provide healthcare support without visiting hospital	Singapore
	· Consulting with a physician is available	

Fig. 1. Apps by Governments [16] link

workplaces provide video that is analyzed by AI software, pointing out behaviors that would normally seem innocuous but could contribute to the spread. This can range from people walking together in a hallway toward a cafeteria for lunch to a supervisor approaching a worker to have a conversation [20].The hope is that such technology can allow businesses and schools to reopen more safely by helping them understand where people tend to congregate and making changes to encourage social distancing — such as by moving furniture around or adding floor markers, or by having real people standing by to keep foot traffic flowing. There have been many attempts to reduce queues at messes etc by attempting software systems that manage queues by pre-booking and give slots [22]. This has been implemented at many workplaces and universities. There have been many attempts by university students to develop such apps [23]. Detroit based app development company Andonix have launched a new app allowing employers to monitor employee health data and social distancing.The app is called Safely. Once inside employees or visitors get a color code on the app allowing them to be in certain places of their workspace. The tracking also creates a heatmap of where employees are too close, in theory letting employers and health officials monitor and adapt social distancing guidelines. Companies like DaleOffice [25] have devised systems where employees could book a room or a desk to work and could avoid overcrowding. They also allow employers to do analysis and plan accordingly. Companies like contaco [26] and iotspot [27] are doing analysis to sanitise the workplace according to maps generated by employee interaction and provide cleaner workspaces. They also help the employer trace contacts, manage hotspots etc.

C. Implementations at Universities for Social Distancing

UC San Diego students use the Waitz app to gauge how busy places are on campus, to keep themselves safe. Students at several other universities already use the Waitz App to find less crowded study spaces on campus. [28] They created a sensor called Occuspace that plugs into a normal electrical outlet. It scans for Bluetooth and WIFI signals in the area to estimate how many people are present. UCI Uses Campus Wi-Fi to profile building floors [29] The data dashboard shows information on UCI building usage focusing on different regions and floors within structures. The university's Wi-Fi network collected the data securely and privately. A crowd flow monitoring tool measures the circulation of people through regions over time. Users can view the dashboard on their mobile devices to help them avoid overly crowded areas, and facilities managers could use the feature to coordinate the cleaning and distancing operations. This way of checking the crowdedness of an area is very effective such that many attempts have been made in this area. [30] Called COVIDU, the app, developed by Harvard University is an interactive tool that factors several important conditions — community transmission, external infection, testing cadence, student population, and other social settings unique to campus communities in modeling the spread on a hypothetical campus and estimating the likelihood of different potential outcomes. The easy-to-use tool allows users to fully customize the range of conditions on which the system bases its calculations. This helps to better mimic the users' own campus community. It also considers the behavior of students and potential visitors, including how many might flout rules and attend social gatherings. The app even models superspreader events and their fallout. The whole algorithm and its code is open sourced. [31] [32]

D. Drone Surveillance

To contain the spread of the virus, governments around the world are taking all the necessary steps to ensure social distancing. Many countries around the world, including China and India, have adopted drone technology for crowd surveillance [2]. MicroMultiCopter, a leading industrial drone manufacturer, has deployed over 100 drones in several cities of China in an attempt to survey areas and observe crowds efficiently. The drones, equipped with sky speakers, can also be used to give instructions to people not in compliance with the guidelines [3]. In India, a technology solutions company named Cyient has provided the Telangana police with unmanned aerial spectrum monitoring technology to help manage crowds. The drones deployed are equipped with surveillance cameras that can effectively monitor sensitive areas in the city and allow the police to handle any unwarranted situation promptly. In addition to crowd surveillance, drones can prove to be highly useful for broadcasting important information, particularly in areas that lack open channels for communication. A night vision camera for monitoring the crowd on drones also has been implemented in these systems. Bloomberg News reported that the Chinese government is using drones to ensure that its citizens are following public health safety guidelines. [4] Drones are also being used for delivery, disinfecting etc.

Type	Capability	Examples
Thermal imaging drone	· Temperature capturing in a crowd	Pandemic Drone
	· Fewer human interactions	
Disinfectant drone	· Sterilizing contaminated areas	DJI
	· Preventing health workers from being infected	
	· Fewer human interactions	
Medical/delivery drone	· Reducing hospital visits	Delivery Drone Canada
	· Increasing accessibility to treatments	
Surveillance drone	· Crowd social distancing monitoring	MicroMultiCopter
		Cyient
Announcement drone	· Broadcasting information about COVID-19	Broadcasting drone in Spain and Kuwait
Multipurpose drone	· Temperature capturing	Corona Combat
	· Disinfecting areas	
	· Crowd monitoring	
	· Broadcasting information	

Fig. 2. Different types of Drones [16] link

E. Robots

A Danish robotics company, UVD Robots, has developed multiple disinfection robots [2]. Robots are being used to replace people for mundane jobs and also for delivering things to infected people. They are also being used to monitor crowds and monitor people remotely.

Type	Capability	Examples
Autonomous robots	· Detecting symptoms	Intelligent Care Robot
	· Controlling social distancing	Spot Robot
	· Preventing medical staff from being infected	
	· Disinfecting and sterilizing contaminated areas in hospitals	
	· Delivering patients' treatments	
	· Checking patients' respiratory signs	
	· Collecting swab tests	
Telerobots	· Reducing the risk of infection for medical staff	DaVinci surgical robots
Collaborative robots	· Lower healthcare workers' fatigue	Asimov Robotics
	· Disinfecting hard-to-reach areas	eXtremeDisinfection Robot
Social robot	· Reducing mental strain	Paro

Fig. 3. Different types of robots [16] link

F. Wearables and BLE systems with Apps

Estimote, a start-up known for its Bluetooth location beacons, has recently developed a set of wearable devices to enable contact tracing at the workplace. This wearable device allows organization leaders to monitor the health status of their employees remotely. A Canadian start-up specializing in blockchain solutions has recently launched a safety system, in the form of an app, known as Civitas.This app determines the ideal time and day for people to go out and buy essential items, to avoid overcrowding.

Type	Capability	Examples
Smart thermometers	· Temperature monitoring	Kinsa, Tempdrop, Ran's Night
	· Increasing the diagnosis rate	iFever, iSense
Smart helmet	· Temperature monitoring	KC N901 in China
	· Capturing location and face image	
	· Fewer human interactions	
Smart glasses	· Temperature monitoring and capturing	Rokid in China
	· Fewer human interactions	Vuzix & Onsight
IoT-Q-Band	· Tracking quarantined cases in case of absconding	Hong Kong electronic wristband
	· Cost-effective tracking	Electronic ankle bracelet in USA
	· Destructible	
EasyBand	· Monitoring social distancing by people	Pact wristband
	· Alert the danger of closeness by LED	
Proximity Trace	· Monitoring workers for social distancing	Hardhat TraceTag
	· Tracing contacts of contaminated employees	Instant Trace

Fig. 4. Different types of wearables [16] link

G. AI

Many countries around the world, including China, India, the USA, and the UK, are adopting the use of AI to enforce social distancing and lockdown measures. [2] In China, Baidu, one of the largest AI and internet companies in the world, has developed computer vision (CV) powered infrared cameras to scan public places. These cameras can not only identify people with high body temperatures, but via the use of their inbuilt facial recognition system, they can also recognize citizens who are not following the lockdown protocols. A similar CV camera system has been deployed in Oxford, England, to monitor if the crowds are following the social distancing measures. An AI-based start-up in the USA - Landing AI [5], helmed by one of the most renowned AI experts in the world - Andrew Ng, has also developed a social distancing detection tool that monitors crowds and alerts the authorities whenever social distancing guidelines are breached.

H. CCTV Surveillance

Video surveillance cameras can be used to monitor how many people are wearing masks and their compliance with social distancing. This has already been implemented in France [7]. In the past Facial Recognition with masks were bad because of lack of datasets, but recently many new datasets were released [8] [18]and this has improved the scenario of masked facial recognition [9] [15]. Also various new algorithms have been introduced in this area. [33]

I. Large Scale Software Systems for Monitoring

DHIS2 [10] is used as a national health information system platform for integrated data management and analysis for program monitoring and evaluation in 70+ countries. It is primarily used for reporting and analysis of routine health data. The DHIS2 Android Capture App is a mobile application designed to function seamlessly with a DHIS2 instance. The Android app supports data capture across all DHIS2 data models, including aggregate and individual-level data for Tracker and Event programs. And the app functions in both online and offline mode. DHIS2 supports mapping of both aggregated and individual data, including showing relations between cases . It supports all the standard chart types like column, line, pie, stacked column and area charts. The Surveillance, Outbreak Response Management and Analysis System (SORMAS) [11] is an open-source, mobile eHealth system that organizes and facilitates disease control and outbreak management, in addition to disease surveillance and epidemiological analysis, for all administrative levels of the public health system. It provides visualisations based on tracking. Many more such large scale software systems are available and many of them are open sourced. [12] [13] [17]. Heat Maps based solution for crowd monitoring has been developed [14]

III. System Architecture

Here in this section, I propose a novel software system specifically designed for IIIT-H Campus and it's community building upon the previous research done in this area and taking inspiration from it.

A. Users

There will be three types of users to this system according to level of access.

- **Administrators**: Users who are in charge of enforcing the Lockdown measures and making sure that the protocols are followed. They monitor the system, analyse the data and make changes accordingly. They also monitor working of the fleet of robots, drones and other technology being used. They have administrative access over the system
- **Students** : These are students of the college. They have access to the various features of the system that will be discussed in the coming section like viewing crowds around the campus, booking desks at lab, booking mess timings to avoid queues. They have access to all the user features.
- **Professors/ Faculty**: These users have access to all the features that students plus some extra privileges like time that they can spend at places, privileged access to areas, permission to accept/reject permission requests from students etc or report to the administrators or schedule meetings with help from administrators following protocols. We will discuss these features in detail in the coming sections.

B. Use Cases

This section describes the proposed workflow and use cases for the system.

- Accounts are created for each of the users by the institute connected to their current CAS Accounts. They login to their accounts using CAS as everyone has this account already.
- The software system will include a mobile app that must be installed by everyone for taking advantage of the service. The administrators will also have access to a Web App based Dashboard (which will show heatmaps, data analysed, functions to control drones, and other technologies used)
- The mobile app installed on everyone's phones will show a UI which shows the crowded places on the campus. The user can avoid going to these overcrowded places to protect themselves.
- We all know how important labs and workspaces are to students. Students can book desks, and spaces for a specific time slot of the day, and visit during their slots to avoid overcrowding of these communal places. If they want a colleague also to accompany then they can specifically request for a paired slot for collaborative work. Same applies for booking places to work around the campus.
- We all know about the crowded messes, and its queues. To avoid such issues, the students can either take the food to their hostel rooms after booking it on the app at a time, book a slot or a table, etc. [22] Students can also view crowdings at messes at different times of the day. The app will also show best times of the day to go out and do specific tasks around the campus after analysing the trends of crowd movement using AI and ML Models.
- Cameras that were already in place will provide video to administrators that is analyzed by AI software, pointing out behaviors that would normally seem innocuous but could contribute to the spread. This can range from people walking together in a hallway, going for lunch or to a professor approaching a student to have a conversation or even a student to student conversation. [29] [20]
- The data collected will be shown to the administrator helping them understand where people tend to congregate and help them in making changes to encourage social distancing such as by moving furniture around or adding floor markers, or by having real people standing by to keep foot traffic flowing or even using drones and robots. [23] [25]
- The system will be synced with the current ID Card Scanners already implemented in Campus and Biometric Systems. This will provide data to administrators on various places around the campus, like the Codes in China [1]
- Using the heat maps generated by the system the administrators can deploy drones and robots to do sanitization to maintain a healthy campus like mentioned in [26]. Based on the same data collected administrators can also issue announcements remotely using drones like in china [1] to effectively control crowding in the campus. If technology permits, then this could be automated to do recorded clips too. Robots could be used to control these clouds and keep them moving especially in messes.
- Through entirety of the campus Bluetooth Beacons could be installed as they are cheap and it could be used to follow a similar model to the Waltz App [28]
- The campus already has a well established Wi-Fi system all around, this can be utilised to generate maps of floors by tracking people like the one implemented in UC Campus [29]. This will create a live flow map on the map along with other data collected.
- Administrators will have access to an interactive tool that factors several important conditions , community transmission, external infection, testing cadence, student population, and other social settings unique to campus communities in modeling the spread on campus and estimating the likelihood of different potential outcomes of various decisions taken by authorities and events happening around the campus. It will have the option to customize the range of conditions on which the system bases its calculations. It also considers the behavior of students and potential visitors, including how many might flout rules and attend social gatherings. It will even model super-spreader events and their fallout. The whole algorithm will be based on the Harvard paper and its code which is open sourced [32]
- Drones and Robots deployed will have Surveillance Cameras and Speakers and these will be controlled by the

administrators from their dashboard. Surveillance system will also use Face Mask detection and alert the users if they are found without masks.

- If anyone on Campus is infected, the administrators can analyse the people who came in contact with the infected person, analyse their risk and inform them. They will be given color coded profiles like in china [1]. Different colors on the apps indicate different levels of risk, with green codes granted unrestricted movement, yellow codes for seven days of quarantine, and red codes for those who required 14 days of quarantine. The administrators can also provide medical help to such users. Sanitization and other preventive measures could be taken at risked areas based upon the tracking results by using the robots and drones. Drones and Robots can be used to provide food, medicine etc to these users to avoid further contact and for communal protection. [1] Electronic wristbands could be provided to such users to track them more effectively like in Singapore.

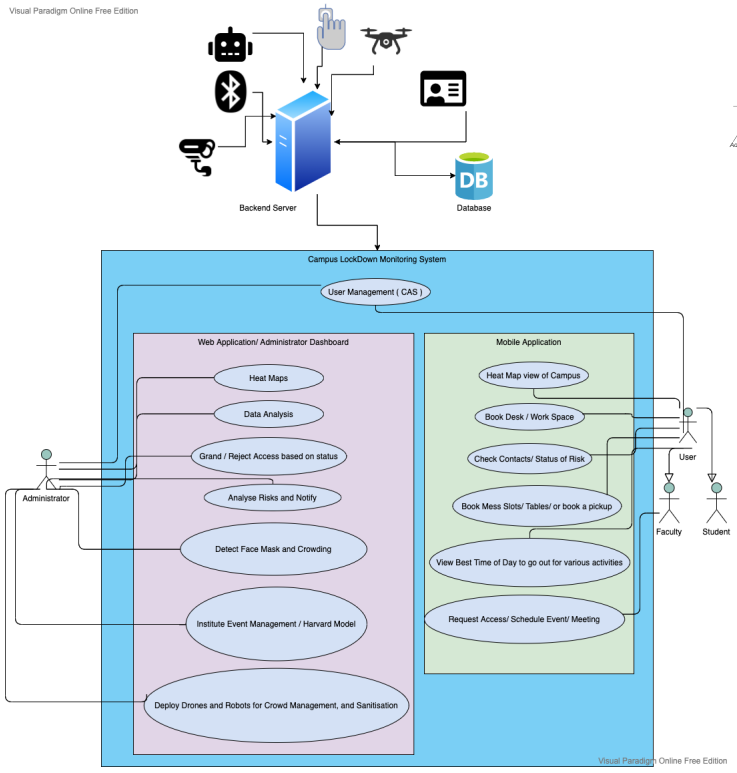

Fig. 5. Use Case Diagram of the system link

C. Classes

The classes are shown in Fig 8

- **User**: The user class represents the normal user of the system. They can be specialised as a Faculty or a Student. They have an id and implement various functions that are specified by the use cases. They are required to follow the protocols and they are being monitored.
- **Faculty**: It is a specialisation of User class that represents the faculty of the institute.

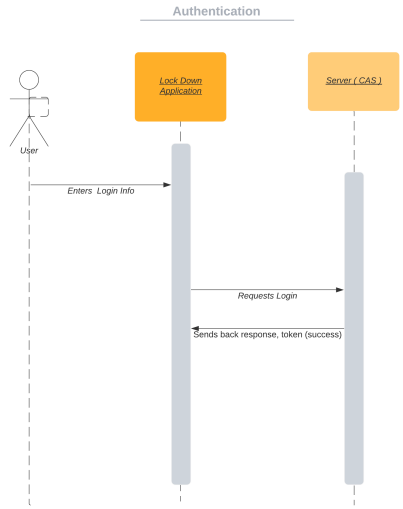

Fig. 6. Sequence Diagram of the Authentication flow link

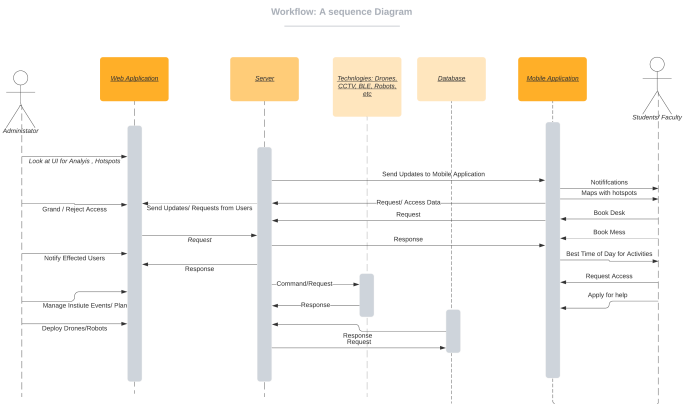

Fig. 7. Sequence Diagram of the main flow link

- **Student**: It is a specialisation of User class that represents a student of the institute.
- **Administrator**: The administrator class represents the administrators of the software system. They monitor the campus lockdown and deploy the systems as required by the situation. They have special access to the system and they also perform the task of managing the system.
- **Database**: This is the class representing the centralised Database of the system. It records the movement data, contacts and other information collected by the system for further use. This data can be used for contact tracing, in case someone gets infected.
- **Robots**: This class represents the robots that are dispersed across the campus for footwork. They help to maintain social distancing by dispersing crowds, making announcements, delivering small things around and do other cases mentioned in use cases. They also help in sanitising.
- **Drones**: This class represents the drones that are dis-

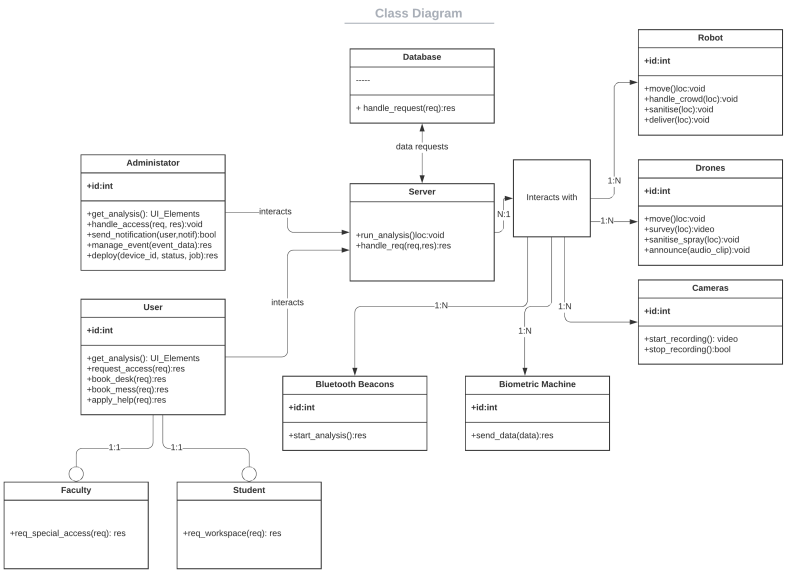

Fig. 8. Class Diagram link

persed around campus to keep a watch on people, their movements and trace heat maps. They are equipped with cameras. They also help in sanitizing.

Other Classes represent the objects they specify

D. Modules and some notes

- **Bluetooth Module**: The system will require installing the BLE Devices on floors to track the devices and to track crowds. The system will implement a system similar to the Waltz App [28]. The advantages to this system is that these kinds of BLE devices are very cheap but it will be challenging to acquire a large number required for the campus on such a short notice and develop for it.
- **CCTV Surveillance**:The proposed system uses CCTV surveillance to track people around the campus. This is very cost effective as IIIT Campus already has these installed and it will be easy to connect this system to it. This should remain the primary surveillance method as drones and Robots are costly and a bit impractical.
- **Drones and Robots**: As mentioned, using drones and robots have a large number of drawbacks. This includes the fact that they are difficult to maintain and are costly. But they can be used in small numbers as they also provide the system with some advantages such as remote monitoring where there is an absence of CCTV. They can spray disinfectants, help in sanitization and can also help in no contact deliveries with people at risk.
- **Recognition Module on server**: The proposed system requires detecting people and faces effectively. The server will require ML models to achieve this use case. YOLO [35] is currently the state of the art system in terms of object detection. YOLO can be used to detect people in video feeds from drones, robots and CCTV on the backend server. It is extremely fast when compared to other classifier based systems. We can use this in the system for our purpose of identifying people and counting them. Alerts can be sent out in case they violate protocols. We will also need to detect masks on peoples faces. The state of the art technology currently is SSDMNV2 [33]. It is a real time DNN-based face mask detection system using a single shot multibox detector.It gives an accuracy score of 0.9264 and an F1 score of 0.93. MRCNet [34] could be used for Crowd Counting and Density Map Estimation in Aerial and Ground Imagery.Using two losses, one at an earlier level and another at the last level of the decoder, MRCNet estimates crowd counts and high-resolution crowd density maps as two different but interrelated tasks.
- **The Prediction Module**: The Prediction Module will implement the COVIDU Model [32] by Harvard University for its prediction hosted on the server. It was specifically designed for this use case.

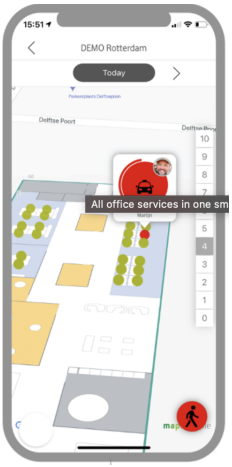

Fig. 9. Proposed UI showing the Map View with crowded places link

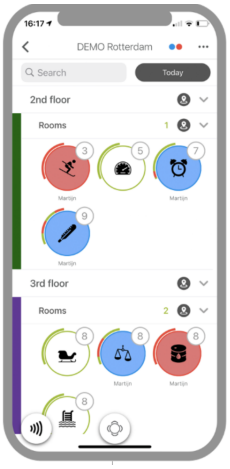

Fig. 10. Book desk at workplace a proposed UI link

Fig. 11. Proposed UI fo the Administration Dashboard link

IV. Conclusion and Future Work

In this paper, I have successfully proposed a software system, which meets the need felt by the institute of identifying clusters of people via surveillance, and to try and restrict the movement of residents in the campus until it becomes normal. It features the ability to study the area wise distribution of clusters of various places across the campus at different times , live, feature various user profiles, a mobile app , a web interface, machine learning models to model campus events and predict fall out based on various factors. The proposed system is inspired by the previous attempts and uses technologies such as Bluetooth Low Energy, CCTV Surveillance, Face detection, Drones, Robots, wifi etc to monitor, sanitise , predict and model a better and safe campus. The system tries to be cost effective by utilising the already existing infrastructure in the campus such as wifi, CCTV. Biometric systems etc. It will help the campus residents stay safe during this pandemic.

There is a lot of scope to the future work that could be done to the system. The system could be modelled in such a way that it relies less on drones and robots as they are costly or much cheaper alternatives could be found out. The UI design proposed is very much bare bones and could improve a lot. The Machine Learning models and systems proposed could have better alternatives that they could be replaced with. One of the other concerns with the system is regarding privacy. This concern could be a paper on its own and requires further research. If the surveillance data lands in wrong hands, then there is a huge chance of Surveillance abuse. The backlash this could lead to needs to be studied. There has been various instances of this in the pandemic especially in other universities where they tried to implement such systems [36]. These need careful study. Many things may need correction in implementation.

Currently, this is one of the best solutions to this problem and I believe this design will help to enforce a Lockdown in the campus and ensure safety of the campus residents.

References

[1] Coronavirus tracking apps: How are countries monitoring infections? link
[2] A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT,Drones,AI, Blockchain, and 5G in Managing Its Impact link
[3] Robots And Drones Are Now Used To Fight COVID-19 link
[4] Drones Take to China's Skies to Fight Coronavirus Outbreak link
[5] Landing AI link
[6] China rolls out software surveillance for the COVID-19 pandemic, alarming human rights advocates link
[7] Coronavirus France: Cameras to monitor masks and social distancing link
[8] MaskedFace-Net – A dataset of correctly/incorrectly masked face images in the context of COVID-19 link
[9] Facial recognition identifies people wearing masks link
[10] DHIS-2 link
[11] Sormas link
[12] Guide to Global Digital Tools for COVID-19 Response link
[13] Digital technologies in the public-health response to COVID-19 link
[14] Insights From Passenger Data link
[15] Asia Today: India to survey 29 million New Delhi residents link
[16] Figures link
[17] Irish contact tracing app is downloaded 1.3 million times and open sourced link
[18] NIST Launches Studies into Masks' Effect on Face Recognition Software link
[19] Going back to work or school? An algorithm may warn you to keep your distance from others link
[20] Carnio link
[21] ISRO Geo Visualisations link
[22] Q-Matic link
[23] Social Distancing: Here's an App for That link
[24] Detroit tech company develops COVID-19 safety app for workspaces link
[25] DaleOffice link
[26] Conteco link
[27] Iotspot link
[28] Headcount App Created to Help University Students Serves New Need Amid Pandemic link
[29] UCI Uses Campus Wi-Fi to Test COVID-19 Contact Tracing App link
[30] LSE students and alumni develop app to help with social distancing link
[31] A safer return to campuses? There's an app for that - Harvard link
[32] CovidU: A Model for COVID-19 Campus Decision Making - Harvard link
[33] SSDMNV2: A real time DNN-based face mask detection system using single shot multibox detector and MobileNetV2 link
[34] MRCNet: Crowd Counting and Density Map Estimation in Aerial and Ground Imagery link
[35] YOLO link
[36] The Pandemic Is No Excuse to Surveil Students link